531. Application of vibration in the wall plastering-covering and cleaning works

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Abstract. Realization of the process of laying of liquid plastic substance on the vertical plane as well as its compacting and packing with the use of vibrations is proposed. Content of air bubbles in the compacted (packed) concrete is diminished down to the minimum due to the vibrational action. Furthermore, destruction of the plastered layer because of action of the frozen water present in pores is reduced significantly due to the increased contact area of concrete with the wall.
Key wards: vibrations plastering; coating; concrete; compacting; packing; plastic.

Introduction

Vibratory engineering and corresponding technologies find more and more increasing application in modern industry and everyday life. Vibratory engineering is widely used in building industry. Namely, vibration plays decisive role in production of the concrete building construction of various forms and purposes, under action of vibrations grains are located tightly in the liquid plaster mass due to banishment of air babbles existent therein, resulting in increase of the plastic mass density several times. These compacted concrete constructions possess much greater strength, durability and reliability in exploitation.

Concrete mixture or plates placed on the vertical wall without compacting and packing contain great number of air bubbles, decreasing not only strength of the plastered layer but also the area of its contact with the wall. This process is significantly amplified in the winter period under negative temperatures. Concrete easily absorbs water through its pores, because of which, due to expansion of the frozen water on the one hand and compression of the concrete on the other hand, great stresses arise both in the space of material and in places of its contact with the wall. Consequently, structure of the plastered material is damaged (loosened) and it comes off the wall prematurely as wall facing plates.

Despite of the above-mentioned aspects, present wall plastering and coating works are still based on hard physical work of a plasterer, thereby not ensuring high strength and reliability of the plastered layer.

Physical and mechanical features and composition of liquid plastic soil, clay, concrete, glass and other substances are different [1, 2, 3]. Requirement for degree of their condensing are different as well. Therefore for each specific case amplitude and frequency necessary for their perfect condensing will be different and for their determination supplementary research work needs to be performed [6, 7].

Notwithstanding many theoretical and practical research works, processes of location of grain tightly and their relative displacement in the loose and plastic substances are not studied yet completely, considering physical and geometric parameters of vibrations and substances under compaction [1, 7].

Series of assumptions adopted on the basis of analysis of processes of compaction, transportation, separation and others allowed us to elaborate quite simplified concrete mathematical models, providing us with expected results with a comparatively satisfactory precision.

Thus, for example, transportation of the loose multi-grainy substance on the vibratory working member can be reduced to dynamics of movement of one grain provided that this grain will be assigned elastic and friction features of contact of the whole of the heap of material with the working member, of course, on condition that process of relative displacements of grains is existent in the heap itself. Or inversely, if we are interested only in relative displacements of grains, then for simplification of the research it is expedient not to consider displacement of the grainy heap relative to the working member and its influence on the dynamics.

Experimental research ascertained that highly elastic details, for example, rubber moves along the working member with sliding, practically without loosing touch with the working member. Here *a* is a vertical component of the working member acceleration of the grain mass center proceeding from elasticity.

The aforementioned is confirmed by the results obtained from both mathematical simulation and experimental studies. For example, if the whole technologic load on the working member is presented by one grain having a great mass, then amplitudes of the vibrator are non-stable. Instantaneous joining of the whole technologic mass to the vibrator mass and loosing touch with it causes the processes of getting of the vibrator in the resonance and getting not of it [1, 7, 8] Fig. 4. And if the same technologic mass is presented by great number of grains, then the vibrator operation is stable (Fig. 5) [4, 5].

In the research of the complicities (comprehensive) mathematical model of transportation of the loose and grainy substances, at first sight, not very serious inaccuracy remained unnoticed in series of works. Imitation of the current shutting by semi-conductor diode, or for the purpose of interruption of the magnetic tension was annulling.

Analysis of the magnetic flow [4, 5] has demonstrated that it is inadmissible to neglect component bcos(ω), since in the result of this, equation of the magnetic flow will be transformed into equation describing another physical process. In inductive electrical circuits current is displaced by 90^0 from voltage, or is behind it. In the result of such annulment of voltage, current remains in the circuit by its maximum amplitude value during the whole half a period and at each following half-period its rise takes place that is impossible in reality. In reality for imitation of the current interruption process by the diode, instead of annulling member bcos(ω), equation of the magnetic flow dumping must be substituted for the second equation of system (2), where self-induction must be envisaged. And what is more, if influence of the technologic load (that is quite little) does not present interest of the research, then it is advisable to apply thoroughly simplified model of the compelled force, as described in works [1, 3, 4, 5, 8].

Numerical procedure

Concrete is a multi-phase substance (water, air bubbles, cement and inert sand particles of various density and size). According to works [1, 2] liquid and plastic concrete is considered as a three-phase system, where all the component particles have spherical forms and they are homogeneously non-elastic. Equation of movement of the three-phase material has a form:

$$\begin{aligned}
&\frac{\partial \rho_i}{\partial t} + div(\rho_i v_i) = 0;\\
&\frac{\partial \rho_i}{\partial t} = -\frac{1}{\rho_i^0}\nabla\rho + \frac{1}{\rho_i}\sum_{\substack{j=1\\ j\notin i}}^{3} K_{ji} + Q_i\\
&\sum_{i=1}^{3}\frac{\rho_i}{\rho_i^0} = 1, \quad \rho_i^0 r^3 = const, \quad \rho_3^0 = const, \quad K_{13} = K_{31} = 0;\\
&r\frac{d^2 r}{dt^2} + \frac{3}{2}\dot{i}^3 + \frac{4\gamma}{\rho_2^0 r}\frac{dr}{dt} = \frac{\rho_0 - \rho}{\rho_2^0} + \frac{1}{4}\left|v_1 - v_2\right|^2 - \frac{2\sigma}{\rho_2^0 r};\\
&\rho_0 = \rho_0(\rho_1^0, c_1), \quad \rho = \rho(\rho_2^0, c_2), \quad i = 1,2,3.
\end{aligned} \tag{1}$$

where K_{ji} is an interaction function between phases; γ-dynamic factor of air bubbles; σ-coefficient of surface tension on the border of basic material and air bubbles; Q_i- external mass forces applied at unit masses of phase *i*.

For ascertainment of functions of separate types K_{2i}; K_{i2} (*i*=1, 2, 3) describing force interactions between basic and small-dispersive phase materials and assumptions are necessary [1, 2]. Furthermore, for solution of system of equations (1) it is necessary to determine additionally boundary and initial conditions according to action of external vibrations. It should be noted that solution of this problem is fairly labor-intensive and practically depends on subjective factors because of which two-phase [3] or one-phase models are used in many cases.

A complete mathematical model of loosing touch with vibratory working member of the electro-magnetic vibrator and joining to it again can be presented for one grain in the following form:

$$\begin{aligned}
&\frac{d^2 x}{dt^2} = -2h\frac{dx}{dt} - \omega^2 x + a\phi^2;\\
&\frac{d\phi}{dt} = b\cos\omega - c(\delta - x)\phi;\\
&s = s_0 + v_0 t - \frac{gt^2}{2}
\end{aligned} \tag{2}$$

where *s* is a trajectory of the grain, obtained by taking into account vertical (due to elasticity) and horizontal (due to coefficient of friction) acceleration, corresponding to vibrations of *x*. The working member is inclined by 20^0 relative to the vibrator.

Results of analysis

Since under action of the vertical force, layers of the heap of grains slide up and down with respect to each other, becoming jammed and freed again, then heap of dry loose grains adopts certain plastic features. This multi-layer heap consisted of grains moves on the working member practically without loosing touch with it, only by sliding on it. Elastic and friction connection between grainy layers can be presented in the following form (Fig. 1) [1]. Damping value between layers ϕ=0.9 and consequently free vibratory movement between them practically is excluded.

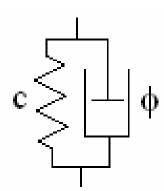

Fig. 1. Connection between grainy layers

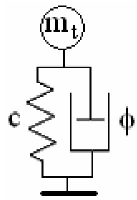

Fig. 2. Model of the system

While in Fig. 2 presents a fairly simplified elastic and friction connection existent between grainy heap and working member, where m_t is a mass of the grainy heap.

Results of investigations are presented in Fig. 3–5.

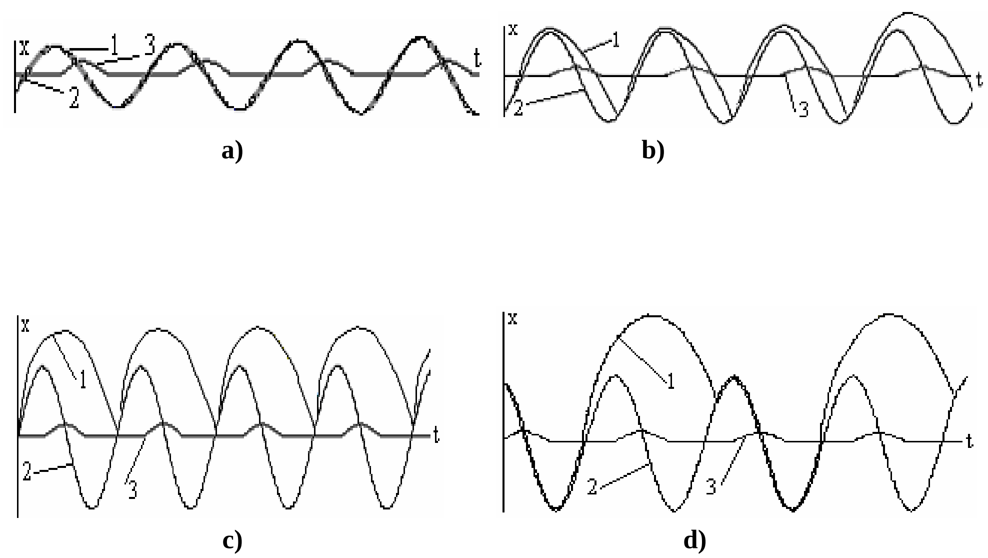

Fig. 3. 1 - trajectories of a grain movement, 2 - amplitude of the working member, 3 - oscillograph of the magnetic flow: a) displacement of a grain without loosing touch with the working member, b), c), d) - with loosing touch with the working member

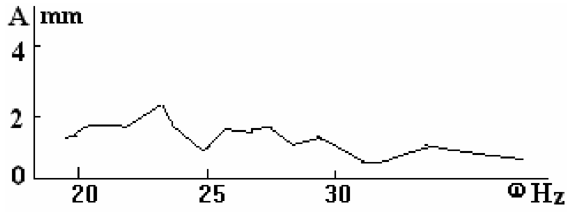

Fig. 4. Amplitude-frequency characteristic

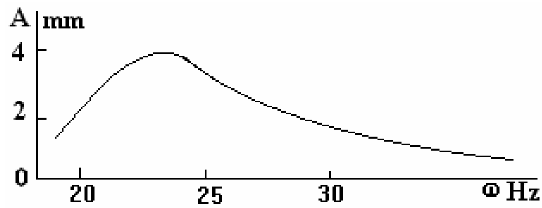

Fig. 5. Soft characteristic of AFF determined by influence of nonlinear forces of electric magnet and of technology loading

Conclusion

In plastering of the vertical plane a special importance is assigned to stickiness of plastic substance (of liquid concrete) since gravitational force is perpendicular to the supporting and condensing forces. Gravitational force, instead of favoring the process of condensing as it is on the horizontal plane, is trying to throw the liquid concrete down and aggravate the process of compacting and fastening of the plastered layer on the vertical plane. Moreover, a force developed due to vacuum generated between the working surface of the vibro-head and concrete, at backward motion of the working member, is trying to tear away the concrete stuck to the wall.

Theoretical and experimental research works have demonstrated that for packing of the plastered substance load on the vertical wall and hardened slightly, it is expedient that a working vibratory head possessed minimum contact area and rounded ends of a rotary cylindrical form is desirable at amplitudes of 4-5 mm, meanwhile at small amplitudes of less than 1-2 mm, it is possible to use a vibro-head with fairly large contact area thereby ensuring an acceptable smoothness of the wall surface. Value of the amplitude depends on thickness and density of the plastered layer and state of the wall surface. For obtaining a plastered layer monolith with the wall it is desirable to use a special devise having barriers for restriction of lateral displacement of the concrete liquid mass.

The essence of deep vibro-densing of grainy materials lies in destruction of the multi-phase liquid structure, banishment of the air existent therein and consequently in disposing of grains tightly. Because of the above-mentioned, density and cohesion of the concrete structure not only increase, but also content of pores existent in the concrete reduces practically down to zero, while its contact area with the wall and, consequently, cohesion increases several times. Due to lack of air bubbles, water-conductivity of the condensed concrete and water accumulation therein drops sharply. Thus, the concrete compacted (packed) as a result of the vibrational action is much more stable and its destruction because of action of the frozen water is reduced down to the minimum.

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